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G1A AA1 AD6 AG16 AG7 AHP AP17 AR6 AS2

(56) Documents cited
GB 2170315 A GB 1319865 A GB 1177239 A
GB 0899895 A EP 0270299 A2 US 4183248 A

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INT CL⁵ G01K 1/16 1/18 1/20 13/04 13/06 13/08

(54) Heatflow balancing thermometer

(57) A sensing surface 10 in contact with a medium or object whose temperature is to be measured is attached to a primary, thermally insulating support 11 which is mounted on a temperature-controlled, thermally conductive barrier 12.

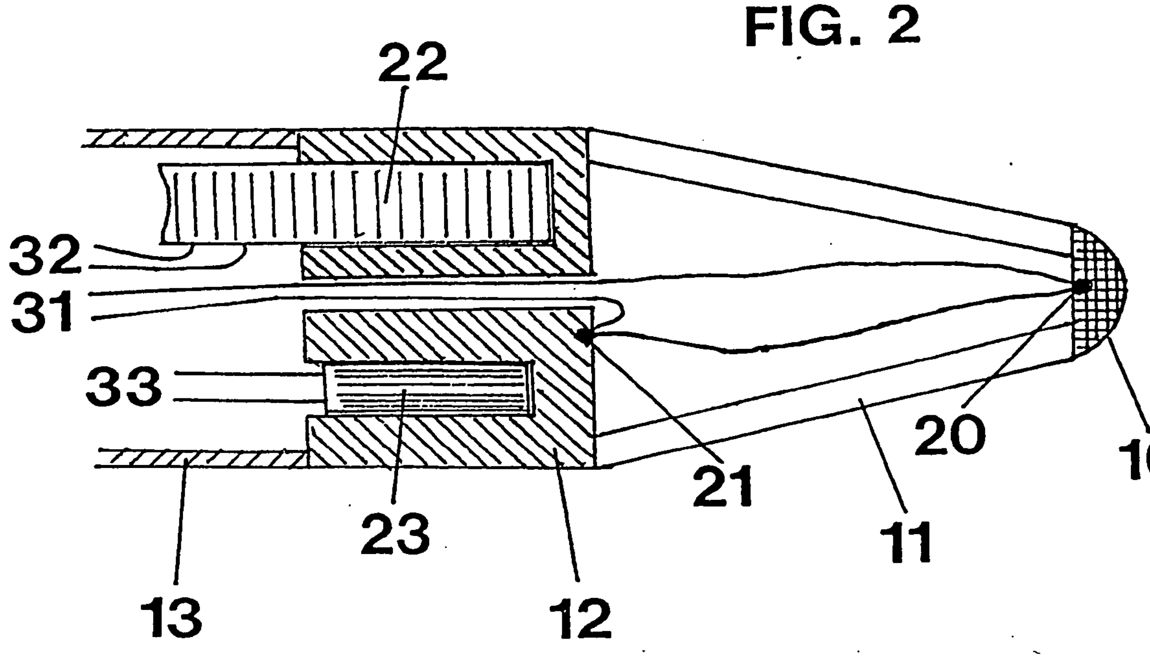
A heating or cooling device 22 and a secondary temperature sensor 23 are attached to the temperature controlled barrier 12. A pair of primary temperature sensors 20 and 21 are attached to the sensing surface 10 and to the barrier 12 respectively.

The signals from the primary temperature sensors pass to an external control circuit, which regulates power supplied to the heating or cooling device 22 in such a way as to cause the temperature of the controlled barrier 12 to follow that of the sensing surface 10.

This enables a secondary sensor 23 of normal size to measure quickly and accurately the temperatures of media and objects which are poor conductors of heat.

A number of embodiments are described including one of sleeve form to fit around a tube containing fluid (Fig. 4); one intended for skin temperature measurement and having a tubular extension of the barrier 12 encircling the measured zone (Fig. 5); one for use as the wet bulb of a hygrometer (Fig. 6); and one in which the barrier 12 is extended to form a telescope tube capturing radiation from a remote body (Fig. 7).

FIG. 2



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The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1990.

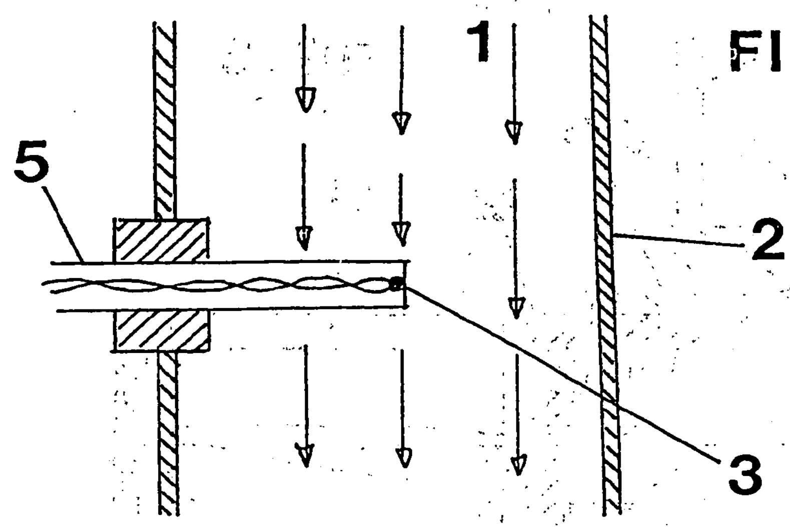


FIG. 1

FIG. 2

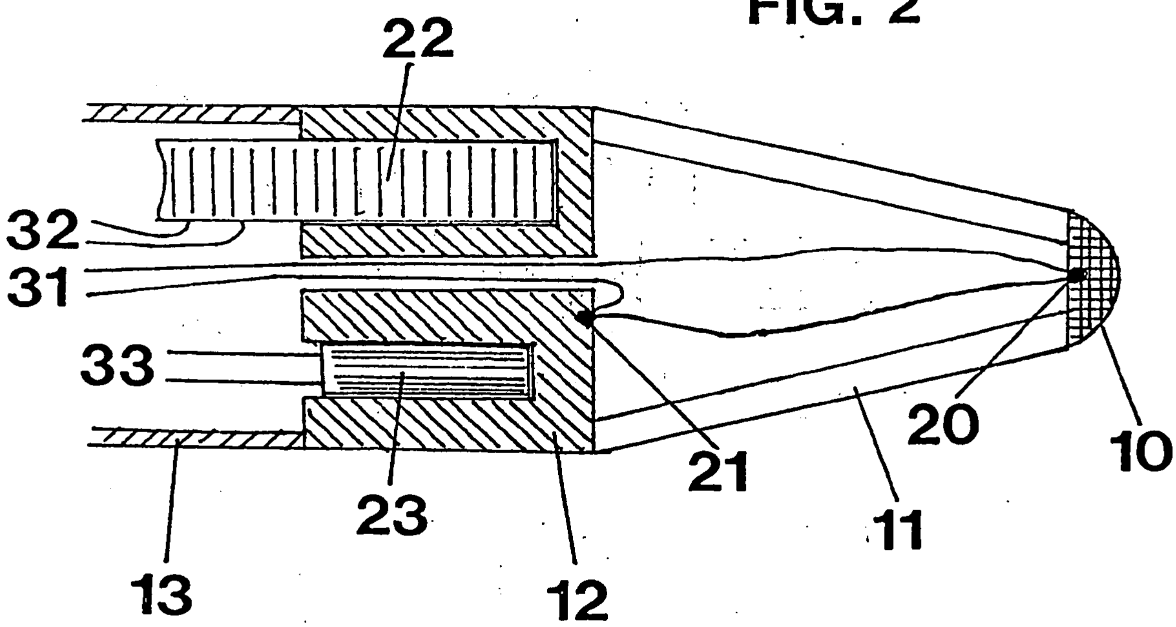


FIG. 3

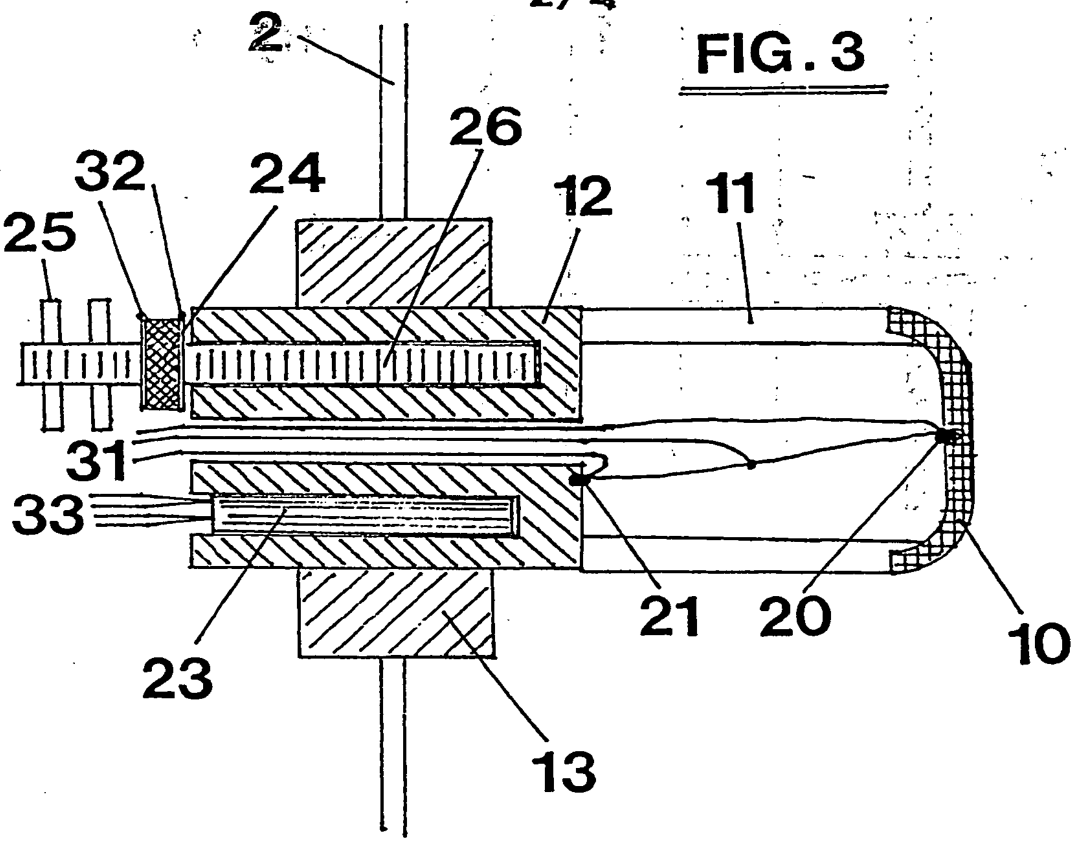
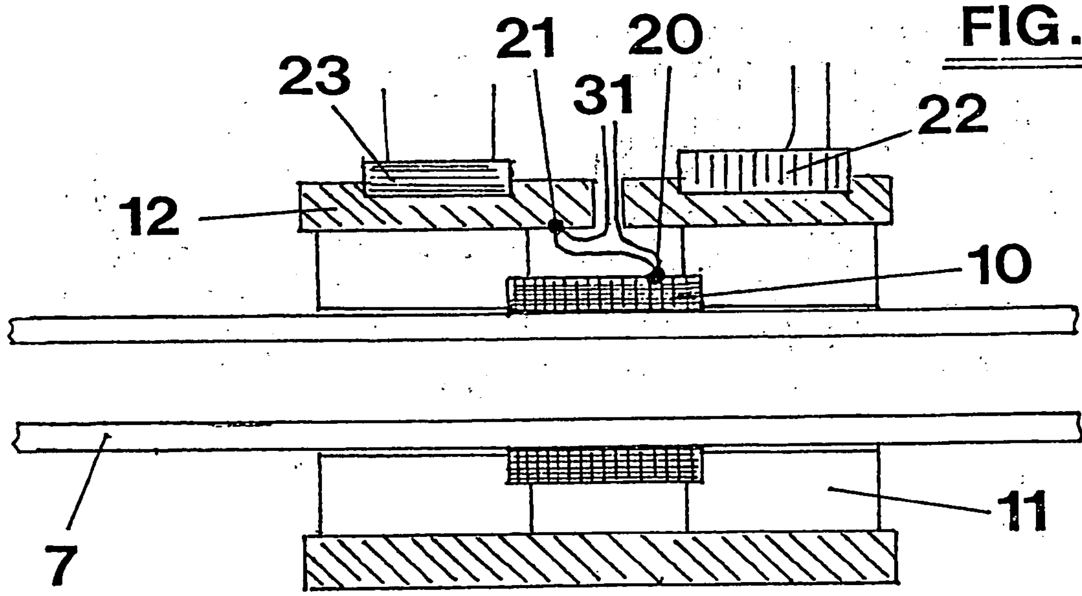


FIG. 4



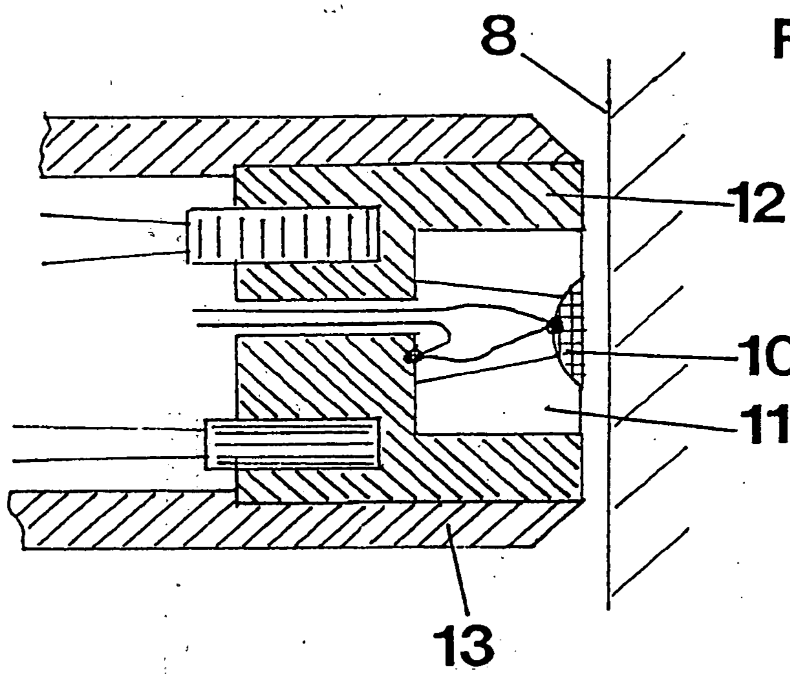
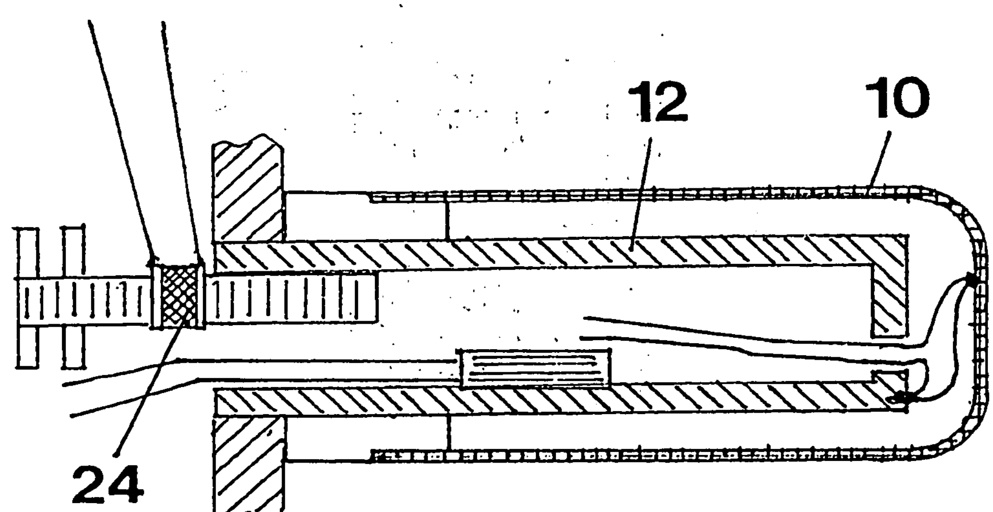


FIG.5

FIG. 6



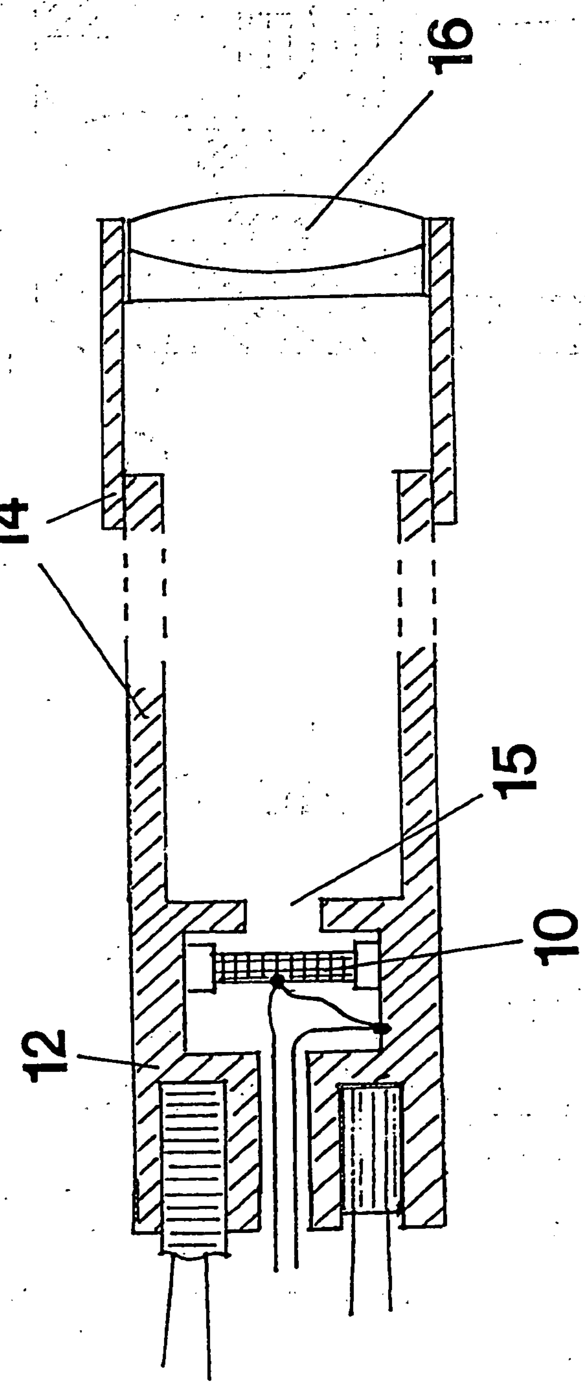


FIG. 7

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HEATFLOW BALANCING THERMOMETER

This invention relates to sensing devices for measuring temperature.

There are a number of known devices for the measurement of temperature, of both electrical and non-electrical types. These include thermocouples, thermistors, resistance thermometers, mercury-in-glass thermometers and gas thermometers. Most of these devices work on a principle which requires that a temperature sensitive component is placed so as to attain the same temperature as the medium, substance, body or object, the temperature of which is to be measured.

However, all the common types of temperature sensor have finite thermal masses, and the leads or supports, sheaths, housings etc. to which they are attached have significant thermal conductivities. This can make it difficult to obtain a satisfactory degree of speed or accuracy when measuring the temperatures of fluids, particulate solids or bodies which themselves have a limited thermal mass or a poor thermal conductivity or both.

For example, a clinical thermometer used in medical tests has to be placed inside some part of the body of the patient to give an accurate result, and it is then necessary to wait for a minute or more until a steady final measurement is obtained. This type of thermometer has to be cooled to well below body temperature in order to be reset before use, and the main reason for the delay is that the tissues adjacent to the thermometer are initially cooled by contact with it, and it takes some time for their temperature to regain its normal level.

If the same thermometer were placed in contact with the patient's skin then the tendency would be for the area of skin in contact with this thermometer to attain the temperature of the thermometer instead of vice versa, and no meaningful medical information would be obtained by such a test, because the thermal conductivity of skin and flesh is not significantly better than that of the materials of which the thermometer is made.

In the case of measurements of skin temperature, one of the better solutions that can be adopted with existing technology is to use very small thermocouples, attached to the skin by adhesive tape. These tiny thermocouples are not very accurate, and the presence of the adhesive tape will have some effect on the heat balance of the skin, so that such measurements may be in error by several degrees centigrade, whereas an accuracy of 0.1 deg. C or better would be desirable if it could be achieved.

Another known solution for measuring skin temperature is to use a scanning thermography instrument, which measures the levels of infra-red radiation emitted by the parts of the body being scanned. However this technique gives relatively poor resolution both in terms of temperature and space. It is able to distinguish temperature differences of a degree or more at separations of a centimetre of more, but it cannot resolve tenths of a degree C nor resolve positions to the nearest millimetre. Moreover this technique requires the area under study to be nude, and to be exposed to cool air for many minutes at a time. This is likely to result in abnormal blood circulation in the area being studied, and to disturb the very temperatures which one is trying to measure.

Similar difficulties arise in attempts to measure the temperatures of poorly conducting fluids or particulate solids if they are at a temperature significantly different from that of the base to which the thermometer is

attached. It may be desired, for example, to measure the temperature of air, oil or grain flowing through a duct, by means of a temperature probe which protrudes through and is attached to the wall of the duct.

Figure 1 shows this situation. A fluid 1 at temperature T1 is flowing through a duct 2, the walls of which are at temperature T2. The temperature sensor is a probe 5 mounted through the walls of the duct, with the actual sensing element 3 at the tip of the probe.

Although the sensing element 3 is within the space through which the fluid is passing, the finite thermal conductivity of its support will cause the sensor to attain a temperature T3, intermediate between T1 and T2. In the steady state the temperature T3 will be such that the heat transferred to the sensor from the fluid by reason of the difference between T1 and T3 is balanced by the heat conducted along the probe support by reason of the difference between T3 and T2. In a transient (unsteady) state, the temperature T3 of the sensor will be changing at a rate determined by the heat flows just mentioned and by the thermal masses of the sensing element and of its support.

This type of problem can be mitigated though *not* eliminated by choosing small, light sensing elements housed in long probes of comparatively low thermal conductivity. But all substances from which probes can be made have a significant thermal conductivity; and, in general, the more accurate types of temperature sensor such as resistance thermometers are larger, have greater thermal mass and need thicker connecting leads than do less accurate types such as thermistor beads or thermocouples.

Another disadvantage of temperature measuring arrangements of the type shown in Fig. 1 is that the heat which flows along the probe 5 in the steady state is withdrawn from or transferred to the fluid under test. In some cases this will have an undesirable adverse effect on either the overall temperature of the fluid or the pattern of temperature distribution within the fluid.

Thus the attempt to measure the temperature of an object or a fluid which is a poor conductor of heat, or has a low thermal mass per unit volume, or both, by applying or inserting a conventional temperature sensor, gives a measurement which is at best inaccurate and slow to respond, and which may also cause undesirable adverse effects on the temperature which one is attempting to measure.

The invention to be described provides a means to overcome the problems cited above. Using these new means, it becomes possible to test poorly thermally conducting media and objects using accurate types of sensor of normal size, in situations where previously even tiny inaccurate sensors were not satisfactory, and in addition the tendency of the thermometer to alter the temperature of the medium under test is either eliminated or very much reduced.

The invention comprises a contact surface of thermally conducting material, a pair of primary temperature sensors of an electrical type, a primary support of thermally insulating material, a temperature controlled barrier of thermally conducting material, a secondary support, a heating or cooling device, an electrical control circuit and a secondary temperature sensor which may be of any desired type which it is practical to fit. The primary support is the mounting for the contact surface and separates it from the

temperature controlled barrier. One of the primary temperature sensors is attached to the contact surface and the other is attached to the temperature controlled barrier. This barrier is mounted on the secondary support. The heating or cooling device and the secondary temperature sensor are both fitted to the temperature controlled barrier. The electrical control circuit senses the difference in temperature between the two primary temperature sensors and regulates the power supplied to the heating or cooling device so as to minimise this temperature difference.

Some examples of temperature sensing arrangements using this invention will now be described, with reference to the attached diagrams, of which:

Figure 1 shows in cross-section a temperature probe of conventional type used in accordance with the known art,

Figure 2 shows a cross-section of an arrangement of one form of the invention,

Figure 3 shows a cross-section of an arrangement according to the invention for use where a probe form is required,

Figure 4 shows a cross-section of an arrangement according to the invention, adapted to measure the temperature of a liquid or gas flowing through a tube,

Figure 5 shows a cross-section of an arrangement according to the invention, adapted for measuring the temperature of a surface,

Figure 6 shows a cross-section of another arrangement according to the invention, for use if a much larger contact surface area is desirable, and

Figure 7 shows a cross-section of an arrangement according to the invention in which the thermal communication between the sensing surface and an observed object is by radiation.

Referring to Figure 2; a contact surface 10, designed to be placed in contact with either a fluid to be tested or a surface etc. to be tested, is mounted on a primary support 11 of thermally insulating material. This in turn is mounted on a temperature controlled barrier 12, which is fixed to a secondary support 13, attached to the external mounting surface, stand etc.

The temperature controlled barrier 12 is made of a material which is a good thermal conductor. A pair of small, matched primary temperature sensors 20 and 21 are attached to the contact surface 10 and to the temperature controlled barrier 12 respectively. The connections to these primary sensors are passed through a hole in the temperature controlled barrier 12. In the case shown, the primary temperature sensors 20 and 21 are a thermocouple, e.g. a Copper-Constantan thermocouple, with the wire of one material (Constantan) connecting sensors 20 and 21 through the primary support 11 and the two wires of the other material (Copper) emerging from the rear of the assembly as leads 31.

Mounted within, and in good thermal contact with, the temperature controlled barrier 12 may be a secondary temperature sensor 23, connected by wires 33.

A heating or cooling device 22, connected by wires 32, is attached to the temperature controlled barrier 12. This may, according to the application,

be rather a simple heating element or one end of a Peltier effect heat pump assembly, in which case the other end of the Peltier assembly, with its heat sink or source, would extend through the secondary support 13.

The output signal from the primary temperature sensors 20 and 21, which in the case shown will be a voltage proportional to the difference in temperature between the contact surface 10 and temperature controlled barrier 12, is connected to an external control circuit (not shown in the diagram), which regulates electrical energy supplied to the heating or cooling device 22 so as to keep the temperature of the controlled barrier 12 very nearly equal to that of the contact surface 10, preferably to within a fraction of a degree C.

Maintaining the temperature controlled barrier 12 at the same temperature as the contact surface 10 eliminates thermal conduction along the primary support 11, and also along the wires which connect the primary temperature sensor 20. As a result, the contact surface 10 will attain the same temperature as the medium being tested. If the contact surface 10 is initially warmer or cooler than the medium, its temperature will start to move towards that of the medium and, as it changes, the temperature of the controlled barrier 12 will follow it, keeping (as far as the system can achieve this) a zero temperature gradient along the primary support 11 so that the contact surface 10 and the temperature controlled barrier 12 will both reach the same temperature as the medium.

While the initial equalisation of temperatures is taking place, the temperature controlled barrier 12 is being heated or cooled, as the case may require, by the heating or cooling device 22, and the medium under test has transferred from or to it only the small amount of heat needed initially to heat or cool the contact surface 10 itself. After the equalisation has been completed, virtually no heat is transferred by the temperature sensor assembly to or from the medium so long as the temperature of the latter is steady, even though the medium may be at a different temperature from that of a duct, container etc. on which the sensor assembly is mounted.

Measurements of temperature may be made by utilising the signals from the primary temperature sensors 20 and 21. However these sensors are preferably of a type chosen for lightness and speed of response rather than absolute (as opposed to relative) accuracy, and better measurements may be made by means of the secondary temperature sensor 23, which can be of an accurate type. Although the secondary temperature sensor 23 is connected thermally to the temperature controlled barrier 12 rather than to the contact surface 10, its temperature is controlled by the system to be the same as that of the medium under test.

The design of this temperature sensing system can take many different forms, to suit different applications.

Figure 3 shows in cross-section a version of the invention for use where a probe form is required. The functions of the various parts are as already described. The secondary support 13 is a piece of insulating material forming part of the mounting bush etc. by means of which this probe may be fixed to the wall of a container or duct 2. The temperature controlled barrier 12 passes through this support, so that all the probe parts inside the container or duct 2 are at the same temperature as the fluid under test.

This ensures that the fluid does not have its temperature altered significantly by the probe and that the measurements are accurate.

In Figure 3, the heating or cooling device is represented diagramatically as a Peltier effect heat pump 24, one side of which is bonded to a thermally conducting bar 26 which is attached to the temperature controlled barrier 12, while the other side is bonded to a heat sink assembly with cooling fins 25.

In Figure 3, three primary sensor connecting wires 31 are shown. The third, central, connection would be needed either if the primary temperature sensors were a thermocouple and it were desired to measure the actual temperature of one or both using an external measuring circuit, or if these temperature sensors were of another type which does not generate its own electromotive force, for example bead thermistors.

Figure 3 also shows a set of four wires 33 connecting the secondary temperature sensor 23. Four such wires might be needed to achieve measurements of the highest precision if this temperature sensor were a platinum resistance element

The assembly shown in Figure 3 is somewhat stubby in shape when compared with a conventional type of temperature probe designed for a similar application. Conventional probes are long and thin in order to minimise heat conduction along the sheath and consequent inaccuracies of measurement, whereas it is an advantage of this invention that such errors are virtually eliminated, so the assembly can be made quite short without loss of accuracy.

Figure 4 shows in cross-section a version of the invention, adapted to measure the temperature of a liquid or gas flowing through a tube 7. In this case the contact surface 10 becomes a sleeve on the inside of a cylindrical assembly. This sleeve 10 is in thermal contact (though not necessarily direct contact) with the fluid. The temperature controlled barrier 12 becomes an outer sleeve, which surrounds the part of the tube containing the contact sleeve and extends beyond the ends of this inner sleeve far enough to eliminate any significant heat flow in the direction of the tube to or from the inner sleeve. The primary support 11 takes the form of a pair of annular rings, separating the inner and outer sleeves.

The heating or cooling device 22 and the secondary temperature sensor 23 are both attached to and in good thermal contact with the temperature controlled outer sleeve 12. As before, the inner and outer sleeves will attain the same temperature as the fluid and will not themselves alter its temperature.

With this arrangement, and also with the other patterns described, the contact surface 10 may be separated from the medium to be tested by a layer of suitable inert material (in the case shown this is the wall of the tube). This intervening material will slow down the response of the system to changes in the temperature of the medium under test, but will not affect the final accuracy. Such a layer might be necessary to prevent either corrosion of the contact surface by the medium or comtamination of the medium by contact with the metal of which the contact surface 10 is made.

Figure 5 shows in cross-section a version of the invention, adapted for measuring the temperature of a surface 8. In this arrangement the probe's contact surface 10 and the surrounding faces of the primary support 11 and of the temperature controlled barrier 12 are placed in contact with the surface

under test, and all three will attain the same temperature as this surface, even if it is a poor conductor of heat or if there is poor thermal contact between the sensor assembly and the surface to be tested.

It will be a characteristic of the arrangement shown in Figure 5 that the whole area of the sensor which is in contact with the surface under test acts as an almost perfect thermal insulator. In practical applications of this method of test consideration should be given to this factor, as the insulating effect of this probe design might have an undesirable effect on the heat balance of the surface under test.

For example, in tests on various areas of the human body, the design of Figure 5 would be appropriate for measuring the skin temperature of an area which is normally insulated by clothing or by hair, but for an exposed area of skin such as the face a design like that of Figure 2 would give better results, as it would interfere less with the normal transfer of heat between the skin and air by conduction and convection, and also by perspiration.

Figure 6 shows in cross-section another arrangement of the invention, for use if a much larger area of contact with the medium is desirable. In this arrangement, an extended contact surface 10 surrounds part of the temperature controlled barrier 12. This form of construction would be advantageous for measuring the temperatures of gases at a low pressure, or in a psychrometer (wet and dry bulb hygrometer).

If the construction shown in Figure 6 were used for the wet bulb of a psychrometer, the wetted wick would surround the enlarged contact surface 10 and the required cooling of the temperature controlled barrier 12 would be provided by a Peltier effect heat pump device 24, as described previously.

Figure 7 shows a cross-section of an arrangement according to the invention adapted for sensing the temperatures of remote objects. A sensing surface 10 is positioned in the focal plane of a lens 16, and an image of the object is focussed onto this surface through an aperture 15. The temperature controlled barrier 12 as previously described is extended to include the aperture and to form part or all of a telescope tube 14, so that the sensing surface 10 is surrounded by tube parts all at the same temperature and no radiated heat from a surface at any other temperature can reach it except that emitted by the observed object.

If the colour temperature of the object is higher or lower than that of the sensing surface 10, the latter will begin to warm up or cool down, the temperature of the telescope tube 14 will be made to follow this and the system will stabilise when the colour temperature of the sensing surface 10 is the same as that of the image of the observed object. For measurements made with this instrument to be accurate it is desirable that the lens 16 should be made from a material which is transparent to the majority of the relevant spectrum of thermal radiation.

CLAIMS

1. A temperature measuring arrangement comprising: a sensing surface of thermally conductive material, capable of being linked thermally to a body, object or fluid to be tested; a temperature controlled barrier of thermally conductive material; a primary support of thermally insulating material, which separates the sensing surface from the temperature controlled barrier; a pair of primary temperature sensors one of which is in thermal contact with the sensing surface while the other is in thermal contact with the temperature controlled barrier; a heating or cooling device, in thermal contact with the temperature controlled barrier; and a control unit which regulates the heat flow between the heating or cooling device and the temperature controlled barrier in such a way as to minimise the difference between the temperature of this barrier and that of the sensing surface.

2. A temperature measuring arrangement as claimed in Claim 1, in which the sensing surface is mounted on or attached to some part of an object or body to be tested, and the temperature controlled barrier effectively surrounds the sensing surface assembly.

3. A temperature measuring arrangement as claimed in Claim 1, in which the temperature controlled barrier is mounted on a secondary support, and the sensing surface is attached to the temperature controlled barrier via the primary support.

4. A temperature measuring arrangement as claimed in Claim 1, in which optical components are arranged to form on the sensing surface an image of the body or object to be tested, and the temperature controlled barrier is shaped to surround the sensing surface except for an aperture through which the image is formed.

5. A temperature measuring arrangement as claimed in Claims 1, 2, 3 or 4, in which the measurements of temperature are made by utilising an indication or signal from either or both of the primary temperature sensors.

6. A temperature measuring arrangement as claimed in Claims 1, 2, 3 or 4, in which the measurements of temperature are made by means of a secondary temperature sensor which is in thermal contact with the temperature controlled barrier.

7. A temperature measuring arrangement as claimed in any of Claims 1 to 6, in which the primary temperature sensors are a thermocouple.

8. A temperature measuring arrangement as claimed in any of Claims 1 to 6, in which the primary temperature sensors are a pair of thermistors.

9. A temperature measuring arrangement as claimed in any of Claims 1 to 8, in which the heating or cooling device is an electrical heating element.

10. A temperature measuring arrangement as claimed in any of Claims 1 to 8, in which the heating or cooling device is one end of a Peltier effect heat pump.

CLAIMS

11. A temperature measuring arrangement as claimed in any of Claims 6 to 10, in which the secondary temperature sensor is a thermistor.

12. A temperature measuring arrangement as claimed in any of Claims 6 to 10, in which the secondary temperature sensor is a resistance thermometer element.

13. A temperature measuring arrangement substantially as described herein with reference to Figure 2.

14. A temperature measuring arrangement substantially as described herein with reference to Figure 3.

15. A temperature measuring arrangement substantially as described herein with reference to Figure 4.

16. A temperature measuring arrangement substantially as described herein with reference to Figure 5.

17. A temperature measuring arrangement substantially as described herein with reference to Figure 6.

18. A temperature measuring arrangement substantially as described herein with reference to Figure 7.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number
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Relevant Technical fields

(i) UK Cl (Edition K) G1A (AHP); G1N (NADC,NAFB, NENT)

(ii) Int Cl (Edition 5) G01K 1/16, 1/18, 1/20, 13/04, 13/06, 13/08

Databases (see over)

(i) UK Patent Office

(ii)

Search Examiner

M G CLARKE

Date of Search

12 AUGUST 1992

Documents considered relevant following a search in respect of claims 1 TO 18

Category (see over)	Identity of document and relevant passages		Relevant to claim(s)
Y	GB 2170315 A	(URANIT GMBH) - whole document	3,6,7,9
X,Y	GB 1319865	(RALL AND HORNBAKER) - see especially figures 2-5 and page 3 line 39 - page 5 line 65 (equivalent US 3542123)	1,2,6,7,9
Y	GB 1177239	(BROWN BOVERI) - whole document	2,6,9,12
Y	GB 899895	(FOSTER INSTRUMENT CO) - whole document	4,6,7,9
Y	EP 0270299 A2	(THORN EMI) - see especially figures 1 and 4	5-7,10
Y	US 4183248	(ASS TO RWB LABS) - see especially column 5 line 7 - column 8 line 35	6,9,11

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

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